

Article

Geographical Modelling of Transit Deserts in Cape Town

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Abstract: The World Bank calculated South Africa's 2018 Gini Coefficient to be 0.63, which made it the world's most unequal country. Such inequality is perpetuated by land-use patterns still influenced by the apartheid past. The resulting urban form necessitates long travel distances, often relying on fragmented transit modes, each with their own geographical and temporal constraints. This study applies work on transit deserts in cities in the global north to Cape Town, aiming to assess the methodological transferability to the global south, and generating case study results. In the Cape Town case, the study first analyses transit deserts based on formal public transport supply (bus rapid transit, traditional bus and train), identifying that ten out of 18 traffic analysis zones were classified as transit gaps (some unserved demand), while three of these zones qualified as transit deserts (significant undersupply). Like its U.S. counterparts, excess supply is found near Cape Town's city centre. In Cape Town, the transit gaps/deserts are partly filled by unscheduled minibuses-taxi. When this informal public transport service is added, the transit deserts disappear; however, half of the transport analysis zones still qualify as having transit gaps. It is, therefore, concluded that informal public transit in Cape Town reduces the transit gap, but does not eliminate it.

Keywords: geographical modelling; public transport; transit deserts; Cape Town; Africa



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1. Introduction

The term “transit deserts” was first used by David Hulchanski of the University of Toronto in his Three Cities Report [1]. The term was an adaptation of the concept of a “food desert,” [2–4], which is an area where there is limited or no access to fresh food. Similarly, transit deserts relate to experiences of limited or no access to public transport. The Martin Prosperity Institute [5] refers to Toronto's inner suburbs as transit deserts, being underserved by the public transport system. Jiao and Dillivan [6] later defined transit deserts as “areas that lack adequate public transit service given areas containing populations that are deemed transit-dependent”. Locating transit deserts within Charlotte, North Carolina; Chicago, Illinois; Cincinnati, Ohio; and Portland, Oregon involved identifying the transit dependent populations as a measure of transit demand, calculating the transit supply, and then subtracting the demand from the supply to measure the gap [6,7]. Transit dependent populations are those who require transit services to get around more than other population groups do [7] and, consequently, this value defines transit demand. Transit supply is measured by aggregating a number of criteria that contributes to better transit access within a designated geographic area. Transit deserts are, thus, defined as areas where transit demand is significantly greater than supply [7].

A study was conducted where we transferred and adapted Jiao's approach in the four aforementioned cities, in the United States, to Cape Town, against the national context of South Africa. We collected geographically coded information and, where the required data was lacking, found proxies to complete the analysis. This paper summarises our findings in relation to whether transit deserts exist in one city in South Africa, how such deserts can be defined, and whether they might share similar traits and characteristics to transit deserts in other parts of the world.

1.1. Characteristics of Transit Deserts

Allen [8] suggests that the characteristics that are unique to transit deserts can be derived from three broad categories, namely: neighbourhood form and physiography; the time and ease of accessing public transport; and the demographics of users. In terms of neighbourhood form and physiography, transit deserts, as currently defined, have an automobile orientated design. These areas have limited land-use diversity and multiple difficulties and inefficiencies associated with the time spent on travel and the ease of accessing public transport. Demographics include the profile of people who use public transport and are influenced by the general perception of public transport service levels. Differences in economic class are frequently perpetuated in the travel mode choice, where bus commuters are often less affluent than riders of light rail [8,9]. Lack of, or inadequate, public transport services in more affluent neighbourhoods may be accompanied by the assumption that everyone drives a car, which may be misguided [8]. Neighbourhoods that are identified as transit deserts may, in fact, have a number of unique characteristics associated with them, such as high levels of transit dependent inhabitants and relatively low levels of transit infrastructure and services.

1.2. Objectives

The studies by Jiao and Dillivan [6] and Jiao [7] introduced the existing method of inquiry and analysis as described in the introduction. A key gap identified in the literature is that the existing method is only defined as applicable to cities in the United States. Our study aimed to address this gap by modifying the methodology to a South African context, where data availability can be problematic. The study aimed to establish whether the concept of transit deserts can be applied to the South African context, using Cape Town as the case city. Furthermore, assuming the application of the transit desert method and definition is transferable to Cape Town, we wanted to question where transit deserts may be identified in this particular city. As available transport data in Cape Town does not follow the same parameters as data captured in the United States, our research proposes proxies to be used in order to complete the analysis.

1.3. The Case of Cape Town

Cape Town was the first permanent colonial settlement in South Africa and has a cultural heritage that stretches much further into the past. The city continues to expand rapidly, with contemporary growth estimated to be from 4,055,580 people in 2018 to an estimated 4,232,276 inhabitants in 2023. This equates to a 0.9% year-on-year growth rate [10]. This is higher than the population growth in the United States, which was estimated at 0.7% in 2017 (according to World Bank data) and significantly lower than that of South Africa at 1.2% in 2017 (World Bank data). The population growth and increased learner enrolments [10] all impact on all-day transport demand.

Internationally documented transport-related challenges are compounded in South Africa by problematic land-use patterns, inherited from the apartheid era, resulting in long travel distances for large portions of the commuter population [11]. The average direct transport cost for the low-income transit users in Cape Town is estimated at 43.1% of the monthly household income [12], much higher than the recommended 10% set out in the White Paper on National Transport Policy [13].

Although rail has historically carried the highest volume of transit trips in Cape Town, the market share has, as of 2014, been sharply decreasing, due to vandalism of both rolling stock and fixed control assets, as well as an institutional collapse. This has reduced the operational capacity of the service, the extent of which has significantly increased road-bound congestion towards the historic city centre [12]. In addition to rail, Cape Town has a conventional subsidised bus service, operated by Golden Arrow Bus Services (GABS). As at January 2017 GABS operates over 3400 unique routes in the greater Cape Town municipal area, not all of which are open to the public.

As part of a national public transport improvement program, launched in 2006, Cape Town introduced the complete first phase of a Bus Rapid Transit (BRT) service, called MyCiTi. This service runs from the historic city centre southwards to Hout Bay and northwards in parallel to the Atlantic coast corridor, in the extreme north terminating in Atlantis (see Figure 1), an apartheid-era satellite settlement. MyCiTi has improved access to the city centre for the Atlantis population, which previously had insufficient transit services.

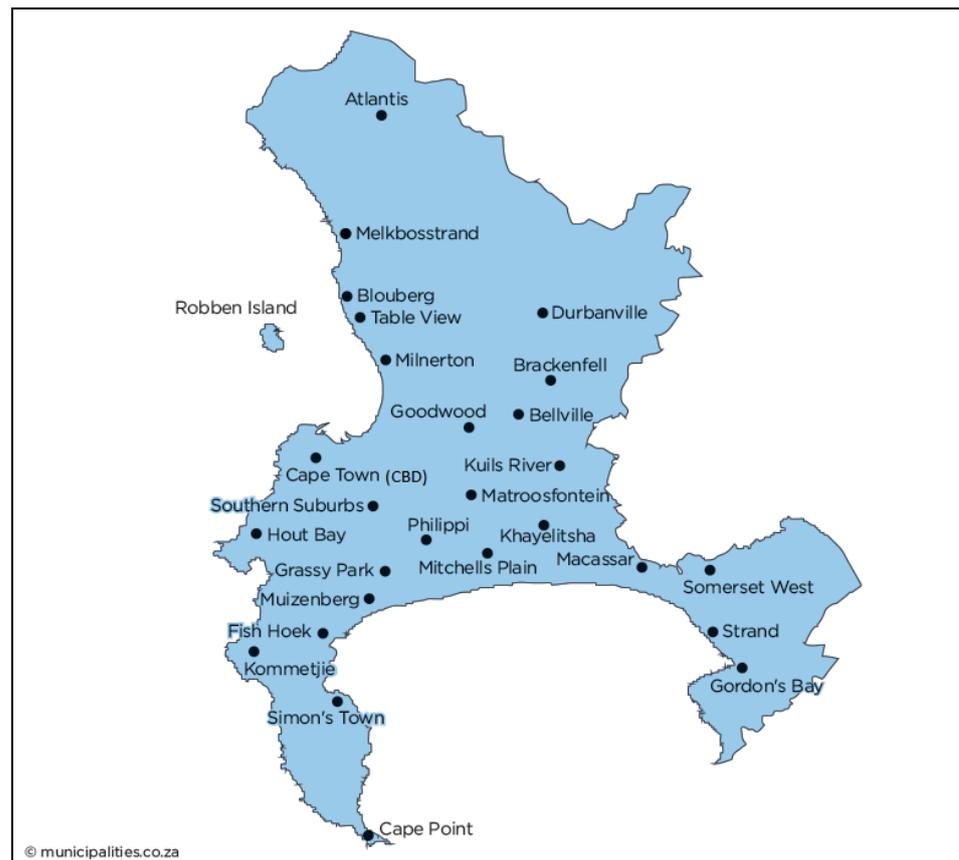


Figure 1. Cape Town in Relation to Atlantis, Khayelitsha, and Mitchells Plain Data. Source: adapted from <https://municipalities.co.za/map/6/city-of-cape-town-metropolitan-municipality>, 4 January 2021.

As of 2014, the second phase of the BRT has been piloted (the MyCiTi N2 Express) along a freeway between the city centre and the southeast of the city, where the largest working-class sub-centres, Khayelitsha and Mitchells Plain, are located (see Figure 1). Although this service has only been in operation for a handful of years, there has been significant pressure on it due to increasing demands on public transport infrastructure in the face of the progressive collapse of the rail service [12].

Institutional public transport in the Cape Town area is complemented by unscheduled van-based paratransit services, known across the country as minibus-taxis (MBT) or taxis. Similar to the situation in many other cities in Africa, Cape Town's paratransit is characterised by underinvestment in vehicle maintenance, fragmented ownership and uncoordinated sectoral management. However, these services also provide accessible and flexible mass transport solutions for urban populations that do not have access to private cars and/or where sprawl renders walking unviable.

The paratransit fare strategy is typically one where the owner and driver agree on a target amount that the driver must pay the owner each day for use of the vehicle. The driver must also pay for fuel and driving-related fines, with remaining fare-box revenue

constituting the driver's take-home pay. This arrangement is one of the key reasons for destructive competition on the road and the overall poor quality of vehicles [14].

South Africa has a well-developed regulatory framework for paratransit services, but it is poorly enforced, and, in effect, there is little public sector intervention in matching of supply and demand. This role falls to owner associations, of which there are estimated to be just over 100 in the Cape Town municipal area. After joining such an association, under its auspices vehicle owners decide on the routes that their vehicle(s) will serve, while drivers make decisions around when during the day or week to operate the vehicle. This arrangement leads to market saturation, with a common result being that associations institute rotational operation amongst their members' vehicles to ensure that each has a chance to secure fare revenue [15].

Although 12% of trips in Cape Town during the morning peak are made by MBT [12], public surveys of paratransit operations are infrequent and not comprehensive. Historically, tense relationships between the public and paratransit sectors also means that the latter is difficult to approach for research purposes. The result is that data is scarce and difficult to obtain.

It is encouraging to see the richness of data that emanates from city-scale mobile phone-based surveys of paratransit services [16,17], but even such efforts will require ongoing public sector support and funding to enable their longitudinal repetition. This, in turn, may allow for approximate service supply frequency to be calculated, as was done in one local area in Cape Town [18].

Finally, it is noteworthy that there is a similar format of paratransit service in U.S. cities, e.g., the dollar vans in New York City documented by Goldberg [19]. Such services provide essential transport, and, in the case of the mentioned study, serve a daily estimated ridership of 120,000 passengers. As in Cape Town, these services are challenging to include in data collection efforts and were excluded from the transit desert literature. In the Cape Town context, however, the magnitude of this mode is so great that we were compelled to include this mode of transport in the analysis.

2. Method

The establishment of transit deserts is based on the gap between demand for travel (by the transit dependent population) and the supply of public transport. Transit demand attempts to identify areas where captive users reside, and where the reason for the dependency is a limited number of vehicles available [20]. Jiao and Dillivan [6] estimate the transit dependent population by deducting drivers (from age 16 years) that have a car available to them and car-poolers from the potential transit-dependent adult household population.

Transit supply, in the case of Jiao [7], was measured using seven criteria [21,22]: the number of rail and bus stops; the frequency of service for each bus and rail stop per day; the number of bus and train routes; the length of sidewalks; the length of bike routes; the total length of low-speed limit roads; and the intersection density.

As indicated, the demand and supply information needed to be adapted, in the South African context, is based on data availability. The data used by Jiao [7] is used as a basis to construct proxy data in the Cape Town case study.

Jiao and Dillivan [6] start their calculation by establishing the number of household drivers. The assumption is that all inhabitants over the age of 16 years are drivers, except the persons living in group quarters (examples of group quarters include hospitals for the mentally or chronically ill, nursing homes, hospices, or prisons). Following this calculation, Jiao and Dillivan [6] establish the transit-dependent household population, which is done by subtracting the number of those carpooling from the number of household drivers. The total transit-dependent population includes the transit-dependent household population, and minors aged 12–15 years, as well as the non-institutionalised population living in group quarters (wardens or nurses, for example).

For the Cape Town case, household drivers are assumed to be the population over the age of 18 years, as that is the legal age to drive a vehicle. The transit-dependent household population is made up of the household drivers minus the vehicles available and the Cape Town carpooling ratio. As the acquisition of a driver's license is not as common in South Africa as it is in the United States, these calculations were amended, and ineligible household drivers were calculated. Ineligible household drivers are household members who are of driving age but not in possession of a driver's license. The transit-dependent population is, thus, based on a summation of the transit-dependent household population, and minors and ineligible household drivers.

Table 1 provides an overview of the data used by Jiao [7], compared with the data used in the case study for Cape Town.

Both studies based the supply on seven indicators. Similar to Jiao's study, the Cape Town study identified the number of rail and bus stops, the frequency of service for each bus and rail stop per day and the number of bus and train routes. However, based on the South African literature [23], the catchment area per stop was extended from 400 m to 1360 m, accounting for service provision and commuter behaviour in Cape Town.

The frequency of (formal and informal) public transport services and routes was established for Cape Town in line with Jiao and Dillivan's [6] approach. The length of sidewalks is, unfortunately, not registered in the Cape Town's asset management system and estimations were impossible as supply varies from road to road. We were, therefore, forced to use a proxy. The available pedestrian related proxy is the number of pedestrian bridges. The length of bike routes, the total length of low speed limit roads and the intersection density are included in the Cape Town case in an identical manner to the Jiao and Dillivan [6] approach.

Once each of the attributes have been measured, the value is divided by the zone size to get the density value, which is, subsequently, converted into a z-score value to standardise the criteria [7]. A z-score is a numerical measurement, used in statistics, of a value's relationship to the average of a group of values, measured in terms of standard deviations from the mean. If a z-score is 0, it indicates that the data point's score is identical to the mean score [24]. In this study, a z-score represents the ideal situation where transit supply is equally accessible by all inhabitants across the study area. The z-scores of the supply criteria are aggregated to represent the level of transit supply for each zone. Once demand and supply z-scores are available, the demand values are subtracted from the supply values and a final value for each zone is calculated [1]. If the difference in the z-score is between zero and negative four, the analysis zone is identified as a transit gap. If the difference in the demand and supply z-scores is more than negative four, the analysis zone is identified as a transit desert [7]. The inverse would indicate an adequate or excess supply of public transport. For Cape Town, the z-scores were calculated for formal transit only, followed by formal and informal transit combined.

Table 1. Transit Demand and Supply Attribute Comparison.

Category	Jiao (2017) [7]	Cape Town Case City	
		Formal Transit	Informal Transit
Demand	Household drivers = (population age 16 and over) – (persons living in group quarters)	Household drivers = (population age 18 and over)	
	Transit-dependent household population = (household drivers) – (vehicles available) * national level carpooling ratio	Transit-dependent household population = (household drivers) – (vehicles available) * Cape Town carpooling ratio [25]	
		Ineligible household drivers = population age 18 and over – household drivers	
	Transit-dependent population = (transit-dependent household population) + (population ages 12–15) + (non-institutionalised population living in group quarters)	Transit-dependent population = (transit-dependent household population) + (population ages 12–17) + Ineligible household drivers	
Supply	Number of transit stops (400 m catchment)	Number of transit stops 1360 m catchment, [23])	Number of transit stops (500 m catchment, experience based)
	Frequency of transit service (based on weekday service)	Number of transit vehicle trips (BRT and rail)	Number of transit vehicle trips (MBTs)
	Number of transit routes	Number of transit routes (BRT, conventional bus and rail)	Number of transit routes (MBT)
	Total length of sidewalks (mi)	Number of footbridges	
	Total length of bike routes (mi)	Total length of bike routes (km)	
	Total length of low speed limit roads (mi)	Total length of low speed limit roads (km)	
		Intersection density	Intersection density
Zone	Block Group	Transport Analysis Zone (TAZ)	
Z-score	Supply–demand	Supply–demand	
Source	Census Transit agencies	South African National Household Travel Survey. Transit agencies Transport and Urban Development Authority. Open Data Portal GoMetro MBT Survey (via City of Cape Town)	

The analysis by Jiao [7] was carried out on Block Group Areas, while in the case of Cape Town, the Transport Analysis Zones (TAZs) were used. TAZs are significantly larger than block groups, which is likely to influence results. However, in the South African situation, data for smaller areas was not available. In the discussion, we will reflect on the effect this has regarding the analysis. The Cape Town municipal area has 18 TAZs. Demand information in this study was based on South African National Household Travel Survey (SANHTS) data from Statistics South Africa (STATSSA) [26]. The SANHTS data includes information on the population, household income, age, vehicle- and driver license ownership per household. The Cape Town carpooling ratio was available from a previous study done at the University of Cape Town [25]. Supply information was provided by transit agencies, the Transport and Urban Development Authority Cape Town (TDACT), and the Open Data Portal (see Table 1).

3. Results

The overall transit dependent population in this study constitutes individuals who have no transport option available to them other than walking. These groups of people were defined as not of driving age, or not being in possession of a driver's license, as well as those households without private vehicles available. Cape Town has a significant public

transport dependent population spread out over a built environment area of 1932 km². Before continuing with the establishment of transit deserts, we decided to compare Cape Town data to three U.S.-based large cities more recently analysed by Jiao [7], using the same method for measuring transit dependency. The choice for these cities was due to all data being available for the year 2013 and the values for factors being spread around the Cape Town values. The comparison (see Table 2) establishes that the Cape Town density of the dependent population, in terms of built environment area, falls within the range of its U.S. based counterparts.

Table 2. Factors influencing transit dependency across four cities (2013).

Measurement	Cape Town	Austin	Fort Worth	Houston
Population (2013)	3,740,026	885,400	792,727	2,195,914
Dependent Population	670,037	130,147	178,059	839,284
Transit Dependent Population	(17.9%)	(14.7%)	(22.5%)	(38.2%)
Area (km ²)	2459	790	904	1624
Built Environment Area (km ²)	1932	772	880	1553
Density (dep.pop/km ²)	346.81	168.68	202.31	540.45

This comparison of Cape Town to cities located in the developed world is viable, since South Africa is considered an anomaly among developing countries, with good infrastructure—including an extensive freeway network—but significant social and economic problems [27]. Cape Town has a relatively large transit dependent population (670,037 people), coming second only to Houston (839,284 people) in the sample cities (Table 2). When comparing the dependent population to the population (2013), Houston has the highest dependency percentage (38.2%) followed by Fort Worth (22.5%) Cape Town (17.9%) and Austin (14.7%). Cape Town’s municipal boundaries extend over the largest area, which increases the probability of dependent populations being further away from infrastructure and services. This is a significant issue, since public transportation thrives on an urban form that is compact and sustained by a stable and ever-increasing population density [28,29].

3.1. Measuring Transit Demand

This section elaborates on the process of determining transit demand for the 18 TAZs in Cape Town. In the first instance, the value for transit dependent persons (transit-dependent population = ((household drivers) – (vehicles available) * Cape Town carpooling ratio) + (population ages 12–17) + Ineligible household drivers (see Table 1)) per TAZ was calculated (Figure 2).

Khayelitsha has the largest transit dependent population (3045 persons per km²). This result was unsurprising, since Khayelitsha is considered the largest and fastest growing township in South Africa [30]. Mitchells Plain/Gugulethu has the second largest transit dependent population (2630 persons per km²) followed by Blue Downs (1231 persons per km²). Analysis zones which exhibited low levels of transit dependency were Somerset West (3 persons per km²), Durbanville (15 persons per km²), and Oostenberg (23 persons per km²). As described in the research methodology section, the transit dependent population in each TAZ was calculated based on age, driver licence-holders, and carpool rates.

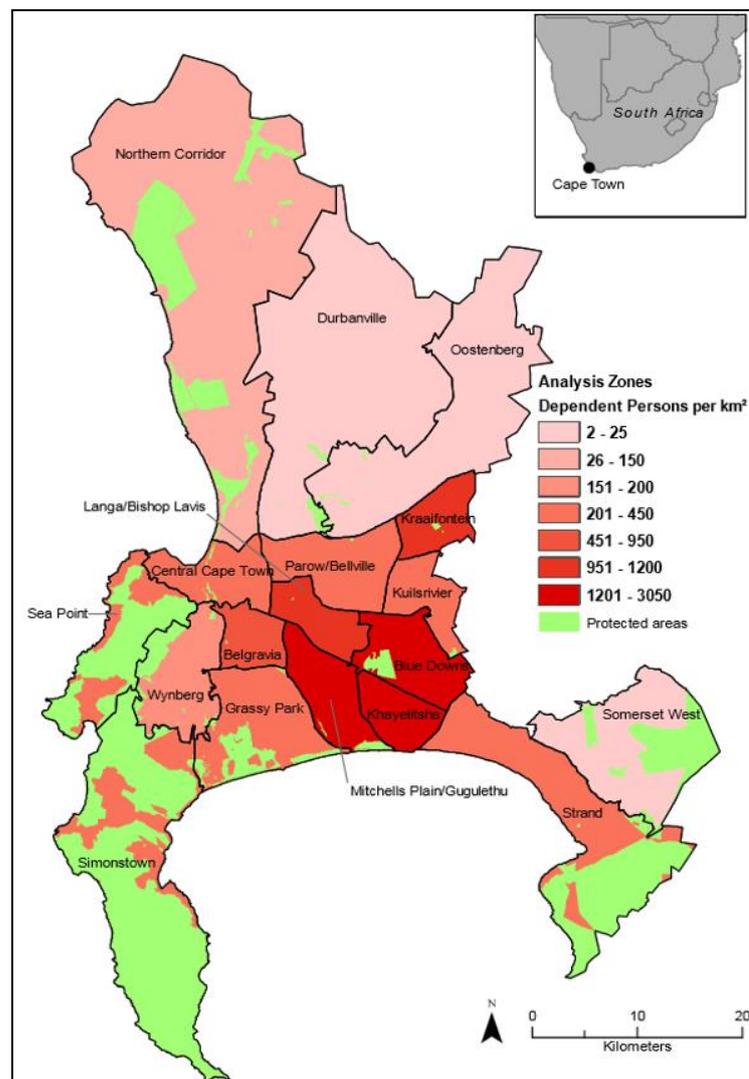


Figure 2. Transit Dependent Persons per km² in 18 TAZs in Cape Town [25,26].

3.2. Measuring Transit Supply

Transit supply is measured in terms of public transport services per km². The number of vehicle trips (BRT and rail) and routes (BRT, rail, and conventional bus) were measured for each analysis zone (also see Table 1). After calculating the z-score, the MBT routes were added. Table 3 reports on these measures in terms of their aggregated z-scores, by ranking analysis zones according to the size of the travel system.

Sea Point has the largest transit supply with approximately 17,500 BRT trips, 400 conventional bus routes, and 30 BRT routes. The extensive infrastructure is attributed to MyCiTi Phase 1, with the presence of all four BRT trunk routes. Additionally, Sea Point has a small built environment area, which covers a substantial part of the Central Business District (CBD) and includes the suburbs of Vredehoek, Gardens, Tamboerskloof, and Bo-Kaap.

Mitchells Plain/Gugulethu, Blue Downs, and Belgravia have the most MBT routes, with 827, 607, and 603 routes, respectively. Mitchells Plain/Gugulethu, Langa/Bishop Lavis, and Belgravia have the highest total number of public transit routes (formal and paratransit combined), with 1892, 1462, and 1443 routes, respectively.

Table 3. Supply Characteristics of the Scheduled Transit System in Cape Town.

Zone	Name	Rail Trips	BRT Trips	Rail Routes	BRT Routes	Bus Routes	Formal Z-Score	MBT Trips	MBT Routes	Total Z-Score
1	Sea Point	0	17,674	0	29	462	4.38	1135	197	3.36
2	Central Cape Town	2379	11,200	8	48	738	2.30	5622	503	2.25
3	Belgravia	252	0	2	0	838	1.66	6049	603	2.43
4	Langa/Bishop Lavis	188	33	2	10	869	1.31	3598	581	1.39
5	Mitchells Plain/ Gugulethu	343	1321	2	7	1056	1.16	17,262	827	2.88
6	Khayelitsha	130	1719	2	4	477	0.46	2778	288	0.33
7	Blue Downs	238	0	2	0	613	−0.16	7007	607	0.37
8	Parow/Bellville	1268	0	4	0	652	−0.26	9743	587	0.25
9	Wynberg	1268	0	2	0	557	−0.37	6815	509	−0.12
10	Grassy Park	126	0	2	0	576	−0.61	5384	349	−0.73
11	Northern Corridor *	0	28,326	0	53	393	−0.92	6993	308	−1.38
12	Kuilsrivier	54	0	1	0	176	−0.95	1928	198	−1.00
13	Simonstown	649	0	1	0	145	−1.08	1836	116	−1.35
14	Kraaifontein	174	0	1	0	46	−1.31	2071	134	−1.28
15	Strand	139	0	1	0	101	−1.37	2244	145	−1.70
16	Durbanville	0	0	0	0	278	−1.4	1199	149	−1.90
17	Somerset West	0	0	0	0	67	−1.42	150	53	−1.92
18	Oostenberg	0	0	0	0	110	−1.44	1685	70	−1.90

* Northern Corridor includes Atlantis. Central Cape Town has the second largest transit supply with approximately 11,200 BRT trips and 2300 rail trips. Cape Town station, which is the main railway station for the city, is found in this analysis zone, and is the starting point for all rail lines through the city, including the Northern and Boland business express lines. This analysis zone has 8 rail routes, 48 BRT routes, and 738 bus routes. Belgravia has the third largest z-score, mainly because of its small geographic area. In addition, a major railway station (Athlone) is found in the centre, resulting in 2 rail routes and 252 rail trips. Belgravia has 838 bus routes.

Oostenberg, Durbanville and Somerset West have the smallest travel systems supply, having no access to either rail or BRT, only being served by conventional bus routes. Both Oostenberg and Durbanville also consist of large geographic areas (see Figure 2), predominantly covering rural farmlands with only the southern portions developed. Somerset West's limited transit supply and, therefore, small z-score, is attributed to not having any BRT or rail services in operation and only 67 conventional bus routes.

Using the rail station and bus stop information, the transit service area was estimated using a 1360-meter catchment. Hitge and Vanderschuren [22] established that transit users in Cape Town walk, on average, 1.36 km to the BRT stop, thus this value is used. This distance is much more than the internationally accepted 400 m [31–33]. Figure 3 provides an overview of the areas that are serviced in the various Cape Town TAZs.

The non-motorised transport system in this study is defined by the four criteria associated with walking and cycling and includes: footbridges, cycle lane lengths, low-speed roads and intersection density (see Table 1). Figure 4 shows the disaggregated and cumulative effect of the four attributes, which constitute the non-motorised transport system.

A neighbourhood's intersection density plays an important role in improving the ease of access to public transport. Previous studies have shown that intersection density is not only an indication of a neighbourhood's walkability, but also plays a significant role in increasing public transport use [34,35]. In this study, Mitchells Plain had the highest intersection density (107.67 per km²) followed by Khayelitsha (90.42 per km²) and Belgravia (89 per km²). Essentially, analysis zones with high intersection densities would contain smaller block sizes, which correlates strongly with encouraging people to engage in non-motorised travel [34].

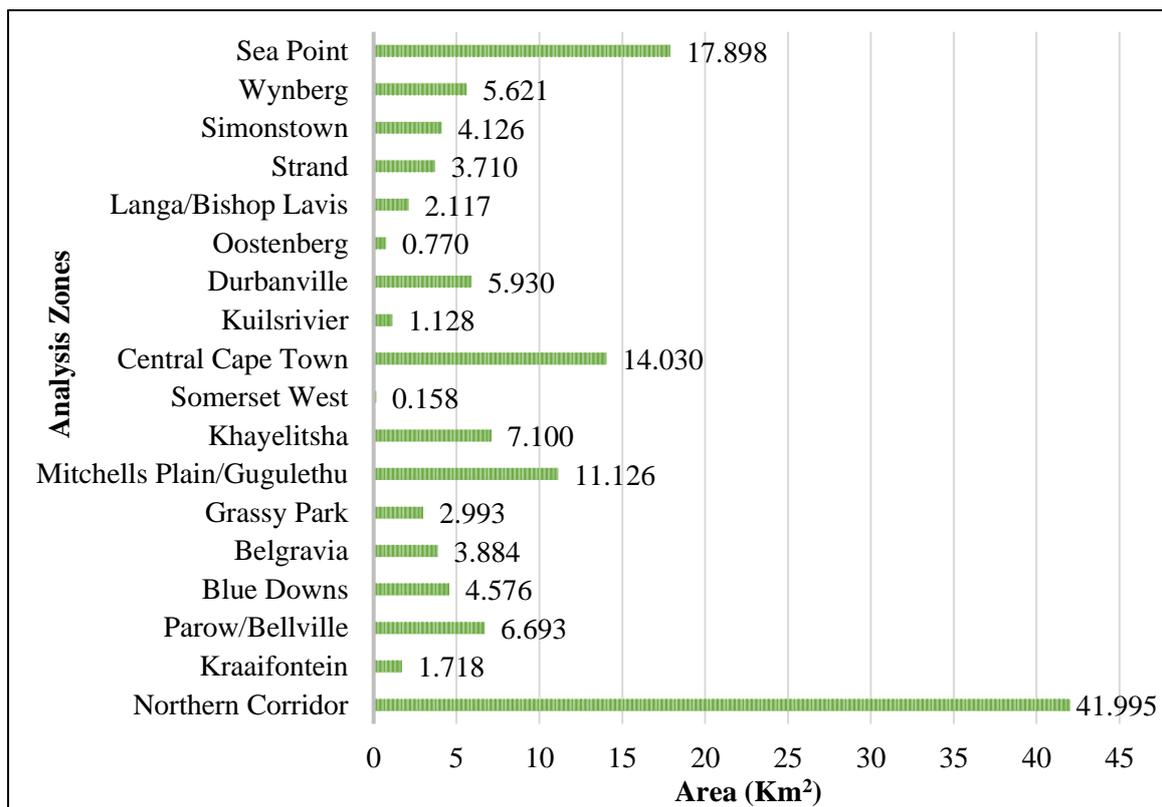


Figure 3. Size of transit service areas for each TAZ in Cape Town (in km²).

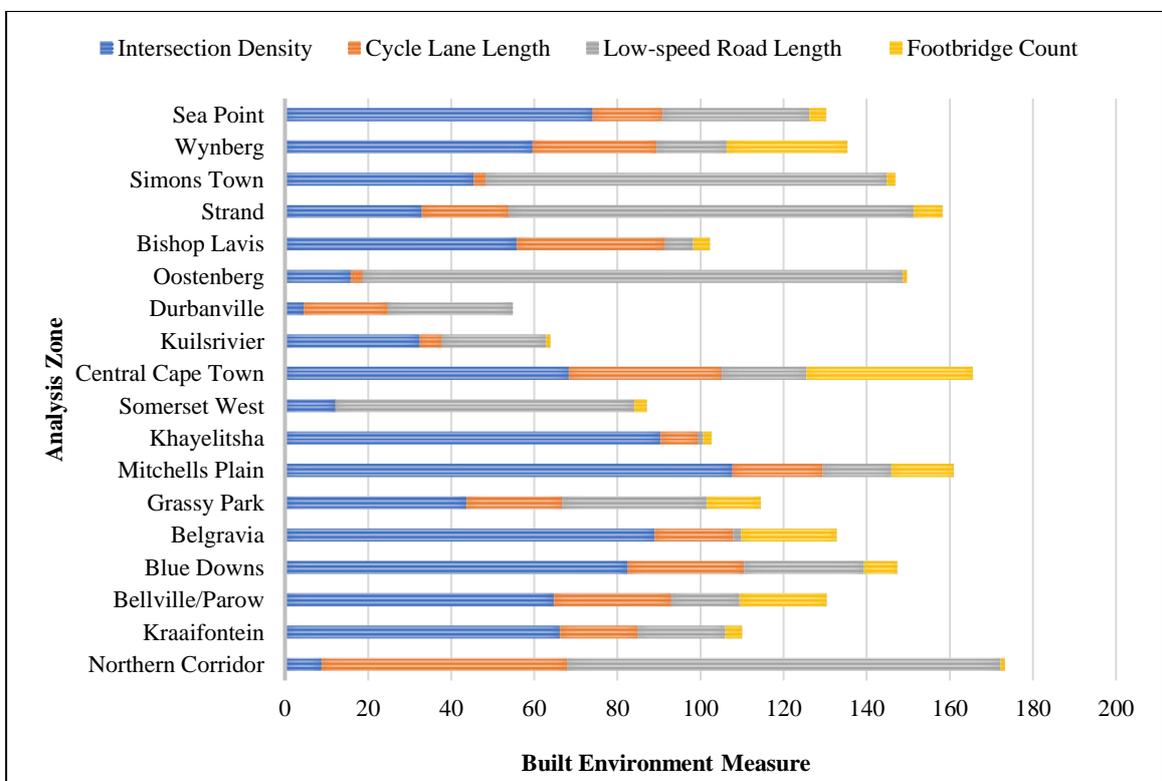


Figure 4. Disaggregated and cumulative non-motorised transport attributes.

The availability of cycle lanes plays an important role in improving accessibility, particularly for non-drivers [36]. The longest cycle lanes can be found in the Northern Corridor (59 km), Central Cape Town (37 km) and Bishop Lavis (36 km). The results of the current study show that Somerset West has the shortest cycle lane length.

Low-speed roads were measured as having a speed limit of 40 kilometres per hour or less, as indicated previously. The analysis zones with the longest low-speed roads are Oostenberg (130 km), followed by the Northern Corridor (104 km) and Strand (97 km). The total length of low-speed roads in each analysis zone has the potential to bring about a large positive impact on safety in the urban environment by creating a more pedestrian friendly environment. There are fewer accidents where the speed limit is lower, and the crashes that do occur are less severe [37].

Footbridges, defined as pedestrian only access over/under motorised transport corridors, aid in providing safe access to public transport. Central Cape Town has the highest number of footbridges (40) followed by Wynberg (29) and Belgravia (23).

3.3. Calculating of Demand and Supply Gaps and Identifying Transit Deserts

Transit deserts were identified through a gap calculation, by subtracting demand and supply z-scores. For supply, z-scores are based on analysis displayed in Table 3 and Figures 3 and 4. Z-scores for demand are based on the analysis shown in Figure 2. The final numerical value, calculated for each analysis zone, determined an excess or lack of supply in relation to the dependent population size. Analysis zones with less supply than public transport demand were shown to have transit gaps, while analysis zones displaying a significant (z-scores of negative four or more) difference were identified as possible transit deserts. Table 4 illustrates the gap calculation and shows the analysis zones in Cape Town with a lack of supply.

Table 4. Gap Calculation for TAZs with a Scheduled Transit Supply Gap.

Analysis Zone	Formal Supply	Demand	Formal Gap	Description	Total Supply	Total Gap	Description
1 Durbanville	−6.49	0.79	−5.70	Desert	−4.57	−3.78	Gap
2 Oostenberg	−5.30	0.78	−4.52	Desert	−4.08	−3.30	Gap
3 Somerset West	−5.10	0.81	−4.29	Desert	−4.21	−3.40	Gap
4 Northern Corridor	−4.69	0.70	−3.99	Gap	−3.61	−2.91	Gap
5 Kuilsrivier	−3.42	0.57	−2.85	Gap	−1.96	−1.39	Gap
6 Khayelitsha	0.31	−2.70	−2.39	Gap	0.58	−2.12	Gap
7 Strand	−2.72	0.45	−2.27	Gap	−2.65	−2.20	Gap
8 Grassy Park	−1.92	0.35	−1.57	Gap	−0.92	−0.57	Gap
9 Kraaifontein	−0.97	−0.30	−1.27	Gap	−1.33	−1.63	Gap
10 Simonstown	−0.32	0.51	−0.19	Gap	−0.81	−1.32	Gap

Based on the formal transport analysis, Durbanville, Oostenberg, and Somerset West exhibit the largest gaps, and are identified as transit deserts. Spatially, these areas are located to the north east and far south east of the city centre in TAZs with mainly affluent suburban neighbourhoods (Somerset West) or residential suburbs surrounded by farmlands (Durbanville and Oostenberg). Urban sprawl and the separation of land-use inherited from modernist and apartheid city models [38] resulted in low-density development, which is not conducive to mass public transport. This left most analysis zones surrounding Central Cape Town, especially areas identified as transit deserts, to be predominantly automobile-oriented. Additionally, the Northern Corridor (which includes Atlantis), Kuilsrivier, Khayelitsha, Strand, Grassy Park, Kraaifontein, and Simonstown, further exhibit a lack of supply, and are shown to have formal transit gaps. These areas are located sporadically across the metropolitan area with no clear spatial distribution.

However, when household income and race are taken into consideration, a clear pattern emerges. These TAZs were overlaid with data related to household income and race, revealing that analysis zones with transit gaps fall into the low-income category, with many households earning less than R4500 (approximately U.S. \$310/€250) per month [39]. Furthermore, these areas are correlated with mainly Black African or Coloured populations [30].

When adding informal transit, the formal transit deserts are converted into transit gaps, indicating that the MBT industry provides an important service. However, half of Cape Town TAZs still show a transit supply gap.

The gap calculation also revealed that certain analysis zones have an adequate supply of formal public transport in relation to the dependent population size, whilst analysis zones displaying a significant difference (a z-value of more than four) are identified as having excess supply. Table 5 illustrates the gap calculation and shows the analysis zones in Cape Town with adequate supply.

Table 5. Gap Calculation for TAZs with Excess Scheduled Transit Supply.

	Analysis Zone	Formal Supply	Demand	Formal Excess	Description	Total Supply	Total Excess	Description
1	Sea Point	10.23	−0.33	10.59	Excess	5.55	5.88	Excess
2	Central Cape Town	7.80	−0.35	8.15	Excess	4.16	4.51	Excess
3	Belgravia	5.01	0.17	4.84	Excess	4.28	4.11	Excess
4	Mitchells Plain/Gugulethu	3.93	2.22	1.71	Adequate	4.71	2.49	Excess
5	Wynberg	0.43	−0.61	1.04	Adequate	0.19	0.80	Adequate
6	Parow/Bellville	0.06	−0.31	0.37	Adequate	0.94	1.25	Adequate
7	Blue Downs	0.98	0.61	0.37	Adequate	1.37	0.76	Adequate
8	Langa/Bishop Lavis	0.59	0.56	0.03	Adequate	2.35	1.79	Adequate

In contrast to transit deserts identified in Table 4, Sea Point, Central Cape Town, and Belgravia are regarded as having excess levels of transit supply. These areas form part of the main commercial and business districts of Cape Town, where public transport needs are well catered for. Belgravia is also well-served, being adjacent to Central Cape Town, and includes commercial (Athlone CBD and Gatesville) and industrial zones (Athlone Industria 1 and 2), while also being served by a large railway station.

When the paratransit services are added, Mitchells Plain/Gugulethu also displays an excess of public transport services. Both areas are densely populated, growing townships.

Please note, this research does not imply that excess supply is an undesirable outcome. The reader can find a visual comparison of the formal and total transit gap analysis based on z-scores in Figure 5. The graph clearly visualises that the scheduled public transport gaps, i.e., the transit deserts are located in the north and, to a lesser extent, the far east of the municipality, and the finding that the MBT industry closes the gap to a large extent (eradicating deserts).

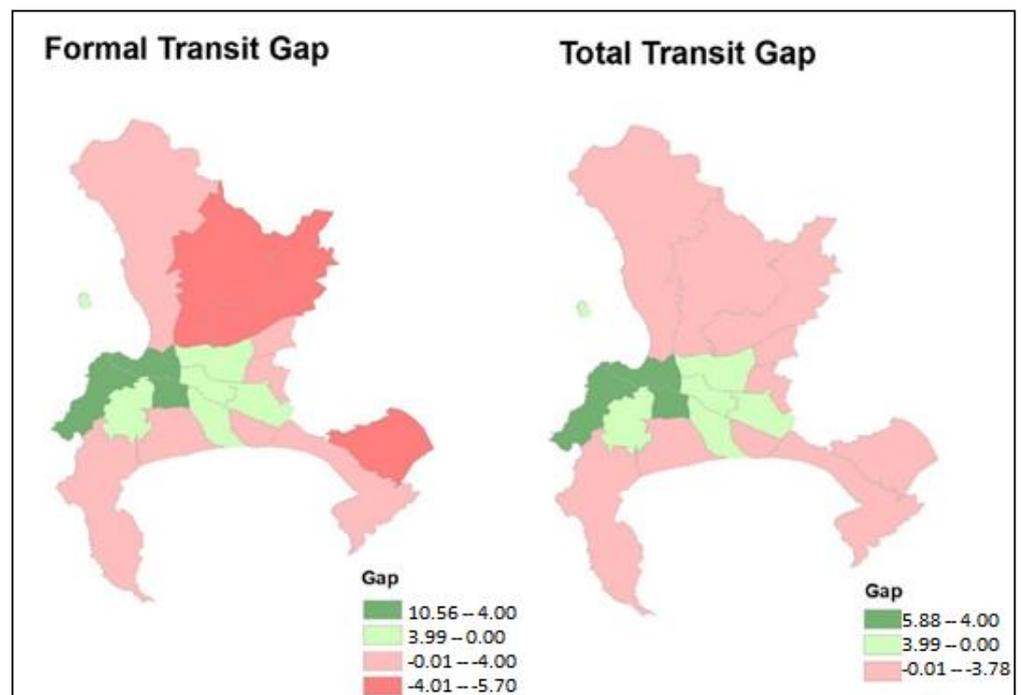


Figure 5. Formal and total public transport gap for Cape Town.

4. Discussion

Applying a modified method, based on the transit desert theory by Jiao and Dillivan [6] and Jiao [7], the results for Cape Town in relation to the transit dependent population are comparable to the case cities researched by Jiao [7]. All cities have areas that qualify as transit deserts, while excess supply is found near the city centres. This is likely the case because, despite South Africa facing significant socioeconomic problems, cities in the country have well-developed urban infrastructure, similar to what can be found in the cities from Jiao's study.

The method to identify the transit dependent population, as applied by Jiao and Dillivan [6] and Jiao [7], was adapted to the South African context, where the driving age is 18 years instead of 16 years, and driver license penetration rate is lower. Regarding supply, the service level was based on the number of scheduled public transport vehicle trips, rather than weekday service frequency, while sidewalk length was replaced by the number of pedestrian footbridges, as sidewalk length is not captured in any asset register. Although transit stop information is available in the South African context, based on the literature [23], it was decided that the catchment area applied should be increased from 400 m to 1360 m, for rail and bus services, to accommodate actual commuter behaviour. For MBT services, which were also included in the Cape Town study, a 500-meter radius was utilised, based on practical experience. Although the use of amended attributes does influence results, the authors are confident that the fundamentals of the methodology are not jeopardised.

Our calculations revealed that ten out of 18 traffic analysis zones had transit gaps, while in two northern zones and one eastern zone, the gap was so severe that the areas could be identified as transit deserts, based on the assessment of formal transit only. The other eight traffic analysis zones had adequate transit supply, of which three had excess supply.

In Cape Town, the MBT industry filled a substantial part of the transit gap. Considering the importance of this form of public transport in South Africa (as well as its larger than expected presence and similar gap-filling role in U.S. cities, for example), further work was conducted. Adding paratransit services revealed that the MBT industry reduced the transit gap and addressed the severe gaps, i.e., deserts. However, paratransit did

not eliminate transit gaps, thus requiring increased (formal or informal) public transport services. This finding should encourage the major public transport actors in Cape Town to cease competing for passengers, thus undermining each other, and to work together to find ways to allocate services more efficiently. Though a challenging process, the latter is likely to grow the overall transit market thus addressing the identified gaps.

The results for Cape Town show a significant contribution by the MBT industry to public transport supply. Given the fact that U.S. cities also provide paratransit services, for example, the dollar vans in New York [19], it would be interesting to see their influence on results in U.S. cities investigated by Jiao and Dillivan [6] and Jiao [7].

The comparatively large geographical size of the traffic analysis zones in Cape Town is unfortunate, as smaller units of geography, such as the block group size used by Jiao and Dillivan [6] and Jiao [7], provide more detailed information. We were, nevertheless, able to calculate transit gaps, and the overall aim of the study, namely obtaining and verifying a method for calculating and quantifying transit deserts in a South African city, was not affected by this issue. As more detailed information becomes available, the information level of transit deserts can, and should, be refined.

Finally, the findings of this study confirm that there are vast inequities in transit availability, in line with broader socioeconomic disparities found across South Africa, including in Cape Town. Identifying and minimizing transit deserts could be a powerful mechanism for bridging the country's economic divide and enable broader and more equitable urban access.

5. Conclusions and Recommendations

This study set out to examine if the transit desert theory, as applied by Jiao and Dillivan [6] and Jiao [7], can be utilised outside of the United States. This study proves that the theory can be applied elsewhere, even though, in the case of Cape Town, some attributes needed to be replaced by proxies, as the required data was not available. This will, to some extent, affect the ability to compare data across international contexts as it is calculated differently.

The use of the transit desert theory has proven to be fruitful. It is recommended that other South African and international cities apply the method developed by Jiao and Dillivan [6] and Jiao [7] to produce transit supply action plans. Such application may include proxy values as tested in Cape Town, where data availability is limited.

Furthermore, although the authors are convinced that the use of proxies did not jeopardise the Cape Town results significantly, the use of large TAZs hinders the development of detailed transit supply action plans. In the case of Cape Town, the collection of data for smaller areas is recommended. This consideration may well also apply in other cities.

The provision of transit services will have an influence on actual demand. Jiao [8] concludes that his method does not include the reciprocal relationship between supply and demand. Including more socioeconomic factors that improves the identification of the transit dependent population is one way of addressing this to some extent. In the South African context, further research is required into the effect that income has on transit dependency. This conclusion is strengthened by the fact that the formal transit assessment revealed deserts in low-income areas. In practice, the need for transit services vary, based on temporal fluctuations (time of day, season, etc.). Further research is recommended into the possibilities to include such temporal fluctuations into the method.

This study highlights the importance of not only looking at formal public transport service, as the potentially great importance of paratransit to address transit gaps and deserts was demonstrated in the Cape Town case. This is likely to be the same in other African cities (and beyond), as paratransit markets have already demonstrated their importance in practice. Paratransit inclusive public transport assessments are, therefore, recommended.

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